

CLAIMS

1 1. A polarization-independent optical isolator/circulator comprising a two-arm
2 interferometer including nonreciprocal phase shifters in both interferometric arms, wherein a
3 nonreciprocal phase shifter includes a half-wave retarder with its slow-axis at 45° , and two sets
4 of transverse magnetic (TM) mode nonreciprocal phase shifters including vertically asymmetric
5 magneto-optical waveguides with a transverse magnetic field across each arm, wherein
6 magnetizations of magneto-optical materials in said arms are opposite to each other to create
7 $\pm 90^\circ$ nonreciprocal phase shift for the TM mode, and said two sets of TM-mode nonreciprocal
8 phase shifters have a half-wave retarder placed between them to rotate the polarization so that
9 both orthogonal polarizations will have $\pm 90^\circ$ nonreciprocal phase shift, allowing the total phase
10 difference between the two arms for forward and backward directions to be different by 180°
11 for both orthogonal polarizations.

1 2. The isolator/circulator of claim 1 further comprising two input ports and one output
2 port.

1 3. The isolator/circulator of claim 1 further comprising a 90° reciprocal phase shift in
2 one arm of the interferometer so that the total phase difference is 0° for one propagation
3 direction and 180° for the other propagation direction.

1 4. The isolator/circulator of claim 3 further comprising two input ports and two output
2 ports.

1 5. The isolator/circulator of claim 3 further comprising one input port and one output
2 port.

1 6. The isolator/circulator of claim 1, wherein the nonreciprocal phase shifter is
2 replaced by a Faraday rotator and half-wave retarders for both arms, where the principal axis
3 of one retarder has 45° offset from the other, and a Faraday rotator and a half-wave retarder
4 are placed in the same order in both arms of the interferometer.

1 7. The isolator/circulator of claim 6, wherein the magnetizations of the Faraday
2 rotators are opposite.

1 8. The isolator/circulator of claim 6, wherein each arm has a plurality of Faraday
2 rotator crystals or waveguide devices, each being spatially separated from the others, and the
3 total Faraday rotation of these devices has 45° nonreciprocal polarization rotation.

1 9. The isolator/circulator of claim 8, wherein the order of Faraday rotators and half-
2 wave retarders are different between the two interferometric arms and the directions of
3 magnetization of the Faraday rotators are the same.

1 10. The isolator/circulator of claim 6 further comprising a waveguide structure at the
2 Faraday rotator and/or a half-wave retarder.

1 11. The isolator/circulator of claim 6 further comprising a thermally expanded core
2 fiber at any input or output ports.

1 12. The isolator/circulator of claim 1 further comprising vertical and/or horizontal

2 adiabatic tapers at any optical interface.

1 13. The isolator/circulator of claim 6 further comprising at least one thin-film magnet
2 adjacent to said one or more Faraday rotators.

1 14. The isolator/circulator of claim 6, wherein at least one of said thin-film Faraday
2 rotators and/or thin-film half-wave retarders are inserted into grooves where these films see the
3 optical beam axis of at least one optical path.

0 1 15. The isolator/circulator of claim 6, wherein at least one of the said half-wave
0 2 retarders comprises stress-applying films.

0 1 16. The isolator/circulator of claim 6 further comprising collimating lenses.

0 1 17. The isolator/circulator of claim 6 further comprising at least one variable phase
0 2 shifter and/or at least one variable attenuator, wherein phase and power compensation in the
0 3 interferometer arms can be passive or active.

1 18. The isolator/circulator of claim 6 further comprising two input ports and two output
2 ports.

1 19. The isolator/circulator of claim 6 further comprising two input ports and one output
2 port.

1 20. The isolator of claim 6 further comprising one input port and one output port.

1 21. A polarization independent optical isolator/circulator based on a nonreciprocal

2 phase shifter comprising:

3 a plurality of Mach-Zehnder waveguide interferometers;

4 a plurality of half-wave retarders; and

5 one or more Faraday rotators with a total rotation of 45° .

1 22. The isolator/circulator of claim 21, wherein one path of each interferometer
2 includes a half-wave retarder, wherein the slow axes of the retarders are either parallel or
3 perpendicular to each other so that, with a proper phase and/or power compensation between
4 the two paths by either active or passive means, a light that enters through one of the input
5 ports is split in the first interferometer into two linearly polarized components and recombined
6 into one of the output ports in the second interferometer.

1 23. The isolator/circulator of claim 21, wherein at least one of the two interferometers
2 is replaced by an interferometer which has a quarter-wave retarder in each path and an
3 additional 90° path length difference between the two paths, and the slow axes of the two
4 quarter-wave retarders are perpendicular to each other.

1 24. The isolator/circulator of claim 21, with one or more Faraday rotators having a
2 total Faraday rotation of 45° and a half-wave retarder with the slow axis at 22.5° relative to
3 one of the slow axes of the retarders of claim 23 in between said interferometers, so that the
4 angle of said linearly polarized light will not change in one propagation direction and will be
5 rotated by 90° in the other propagation direction.